Guidelines for Selecting Open Channel Meters

The term "open channel" refers to any conduit in which liquid flows with a free surface, generally called canals or irrigation ditches. Sharp-crested weirs and ramp flumes are widely-used primary devices for measuring water in open channel systems. Mathematical calculations are used to determine the instantaneous rate of diversion (Qi) at various depths of water flowing over the structure. A rating curve is developed from calculations (which may be double-checked by taking readings on the weir blade with stream gauging equipment). A rating curve is then developed into a rating table for the user. The user reads the depth of the water flowing over the weir or flume by reading the staff gauge on the weir, locates the depth reading on the rating table (see Figure 1)and finds the rate of flow (Qi) from the table. For instance, a reading of 0.2 on the staff gauge means that 0.046 cubic feet per second is passing over the weir. Similar rating tables are constructed for any sharp-crested weir.

Discharge of 90° V-Notch weir in cubic feet per second (cfs)

Head in feet	Discharge in cubic feet per second		Head in feet	Discharge in cubic feet per second
0.02	0.0002		0.16	0.0264
0.03	0.0004		0.17	0.0307
0.04	0.0008		0.18	0.0354
0.05	0.0015		0.19	0.0405
0.06	0.0023		0.2	0.0460
0.07	0.0034		0.21	0.0519
0.08	0.0047		0.22	0.0583
0.09	0.0063		0.23	0.0651
0.1	0.0082		0.24	0.0723
0.11	0.0104		0.25	0.0800
0.12	0.0130		0.26	0.0882
0.13	0.0158		0.27	0.0968
0.14	0.0190		0.28	0.1060
0.15	0.0225		0.29	0.1156

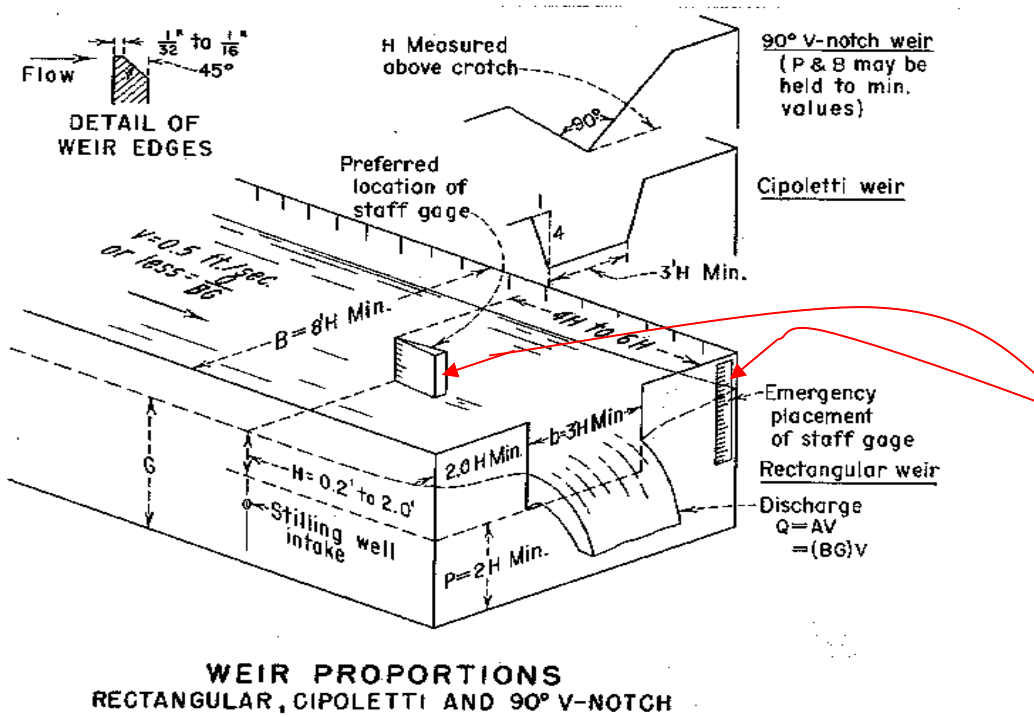
Figure 1. Rating table for a V-notch weir

Sharp-crested weirs

Sharp-crested weirs consist of vertical plates with sharp crests. This type of weir operates on the principle that an obstruction in a channel will cause water to back up, creating a high level (head) behind the barrier. The head, or depth of water flowing over the weir, relates to the rate of flow over the weir; the deeper the depth of water flowing over the weir blade, the higher the rate of flow.

The selection of the type of weir to use is based on the range of flows to be measured, the accuracy of measurement needed, and the most economical geometry that fits in the given channel. Weirs are classified according to the shape of the notch, or weir blade through which the water passes. The basic types are V-notch (Figure 4), rectangular (Figure 5 and 6), and Cipolletti weirs (Figure 7). V-notch weirs (Figure 4) are good for flows as high as about 13.7 cubic feet per second. Rectangular weirs (Figure 5) are good for flows as high as about 607 cubic feet per second, which would be a weir 20 feet wide. Cipolletti weirs (Figure 6) are good for flows as high as about 150 cubic feet per second for a 9 foot weir.

All weirs need to be designed to specific standards for accuracy. Accuracy should be ±5 % of actual flows. The criteria to be met to ensure that accuracy is as close as possible are shown in Figure 2.



H = depth of water passing over the weir blade, where H is measured above the weir blade
b = length of weir crest, which should be 3 times the maximum depth of water to flow over the weir blade
B = the width of the approach channel before the weir blade; 8 times the maximum head is optimum
P = height of the top of the weir blade above the bottom of the weir pool
The staff gauge should be in the center of pool back of the weir blade at least 4 times the maximum depth of water to flow over the weir blade, or if on the side in a quiet part of the pool and outside where the water begins accelerating through the weir blade (the area where drawdown in the pool begins)

Figure 2. Proportions in sharp-crested weirs that must be met to obtain accurate measurement.

The following general rules should be observed in the construction and installation of weirs (Figure 3). The sharp-crested weir selected should be one that best fits the circumstances and conditions at the site of measurement. Usually, the rate of flow expected can be roughly estimated in advance and used to select both the type of weir to be used and the dimensions of the weir. The following criteria should be considered when a specific type of weir is selected for a given application:

- The head of water flowing over the weir should be no less than 0.2 feet and no greater than 2.0 feet for the expected rate of flow.
- Weir length should be selected so that the head for design discharge will be near the maximum. For the rectangular and Cipolletti weirs, the head should not exceed one-third of the length of the weir. That is, if the maximum head is, for example, 1.0 feet, the length of the weir should not be less than 3 feet.
- Set the weir at right angles to the direction of flow in a channel that is straight for a distance upstream from the weir at least ten times the length of the crest of the weir.

- The crest and sides of the weir should be straight and sharp-edged. Each side of the V-notch (Figure 4) weir should make a 45° angle with a vertical line through the vertex of the notch. The crest of the rectangular (Figure 5 and 6) and Cipolletti (Figure 7) weirs should be level and the sides should be constructed at exactly the proper angle with the crest.
- Avoid restrictions in the channel below the weir that would cause submergence. The crest must be placed higher than the maximum downstream water surface to allow air to enter below the nappe.

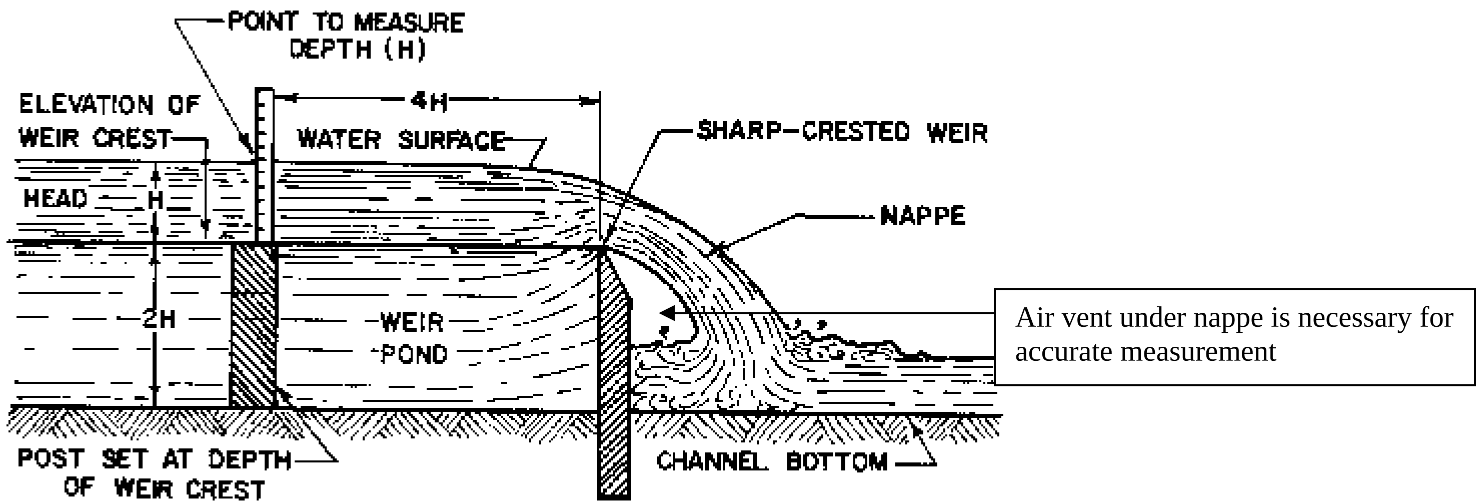


Figure 3. Profile of a properly constructed and operating weir with the nappe properly ventilated.

<u>V-notch weirs</u> are suitable for a wide range of open channel flows from 0.0082 cfs to about 13.7 cfs. V-notch weirs are very accurate at flows of 1 cfs or less. Depending on the situation and location, V-notch weirs are an inexpensive method for measuring small flows. See figure 2, above, for proper proportions.

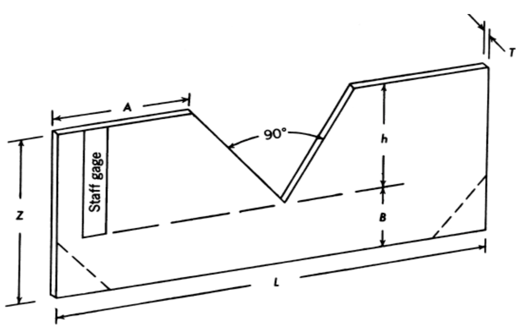


Figure 4. Example of a V-notch weir.

The rectangular weir is a standard weir frequently-used in irrigation. It is simple to construct and easy to maintain. Rectangular weirs are typically designed for weir blades from one foot to twenty foot in length. Rectangular weirs may be the fully-contracted using a weir blade (Figure 5, below) or suppressed (Figure 6, below). Suppressed rectangular weirs are also rectangular in shape, but do not have sides on the blade.

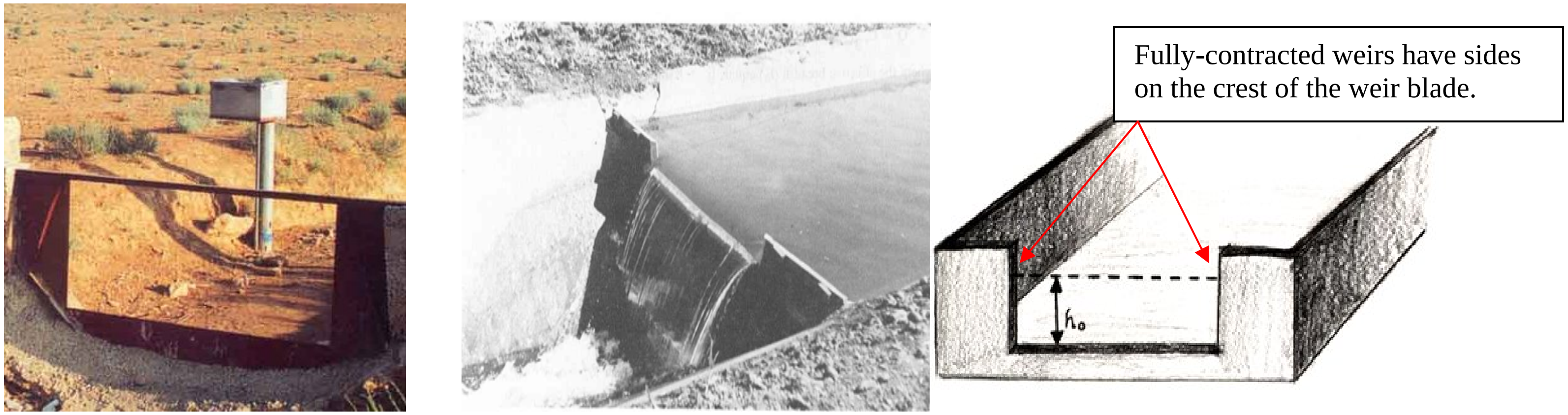


Figure 5. Example of fully-contracted rectangular weirs (note that h_o is the head (or depth) of the water flowing over the weir). This type or rectangular weir requires a weir blade with sides.

Figure 6. Example of a suppressed rectangular weir.

The Cipolletti weir is trapezoidal in shape (Figure 7, below). The slope of the sides, inclined outwardly from the crest, should be one horizontal to four vertical. That is, the slope is 4 inches of rise to 1 inch of run.

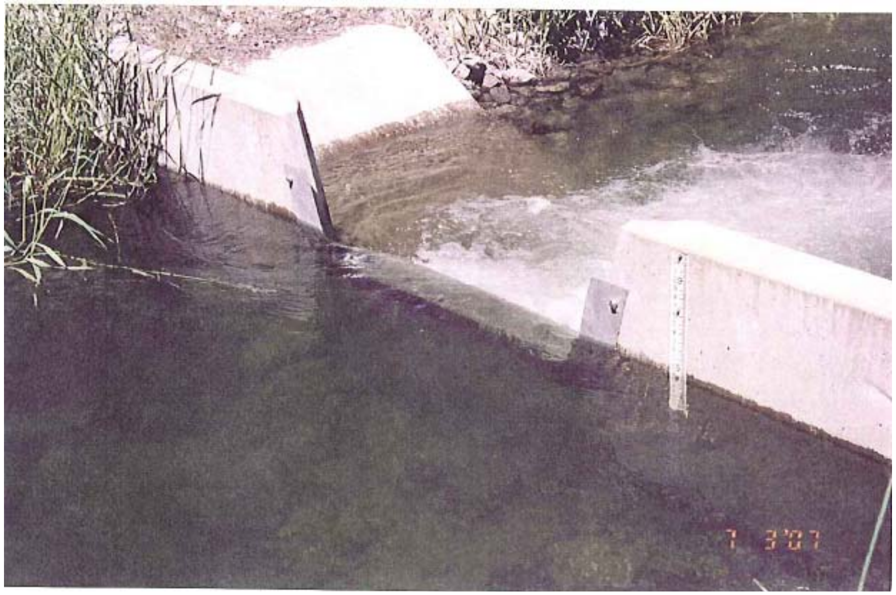


Figure 7. Example of a Cipolletti weir

Conditions in the Pool Before Water Drops Over the Weir

To be sure measuring water is accurate, the channel upstream should be large enough to allow the water to approach the weir in a smooth stream, free from eddies, and with a mean velocity not exceeding 0.5 foot per second or less (Figure 8 compared to Figure 9). The weir pool should be deep and free of sediments (Figure 10 compared to Figure 11), and the weir blade maintained.

Figure 8. Condition of water approaching the weir is good, length of straight flow good, surface smooth and flow is slow

Figure 9. Conditions of water approaching the weir are incorrect, flow is not straight, surface is rough and flow is too fast

Figure 10. Weir pool is full of sediments, preventing the water from pooling correctly behind the weir for accurate measurement

Figure 11. Weir with weir pool clean and free of sediments, ensuring accurate measurement

Figure 11. Weir with no weir blade and staff gauge improperly placed; accurate measurement is not possible

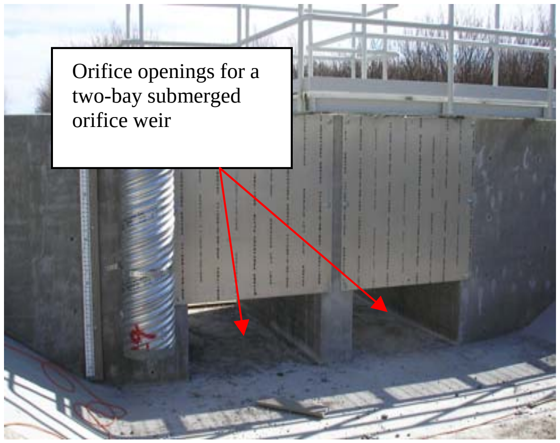
Figure 12. Weir blade properly maintained, staff gauge properly placed to the side, ensuring accurate measurement

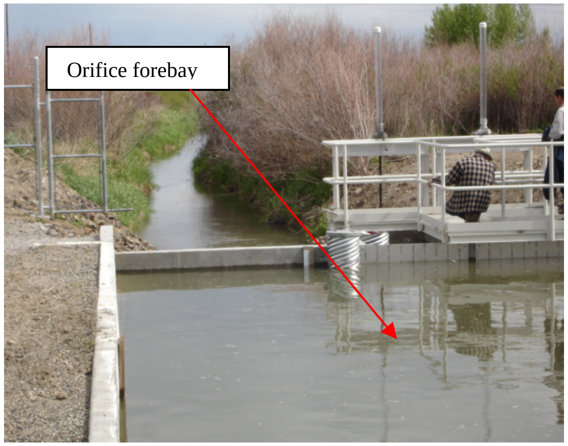
The Suppressed Submerged Orifice Weir

Another type of weir is the suppressed submerged orifice weir, a weir with an opening under the surface of the water (Figure 13). Submerged orifices conserve head and are used where fall is insufficient for weirs. Submerged orifices can be used where cost, space limitations, or other site conditions do not justify a weir or flume. Two advantages of the suppressed submerged orifice weir are:

- it allows accumulations of debris and sediment to pass through the orifice, preventing buildup of sediments in the weir pool, and
- it makes it easier to maintain proper submergence of fish screens by maintaining the necessary depth in the forebay (Figure 13) without sacrificing ability to manage the rate of diversion.

Suppressed submerged orifice weirs have been used successfully in the Yakima Basin in conjunction with fish screens where proper submergence and operation of the screens had not been possible under all ranges of flow.





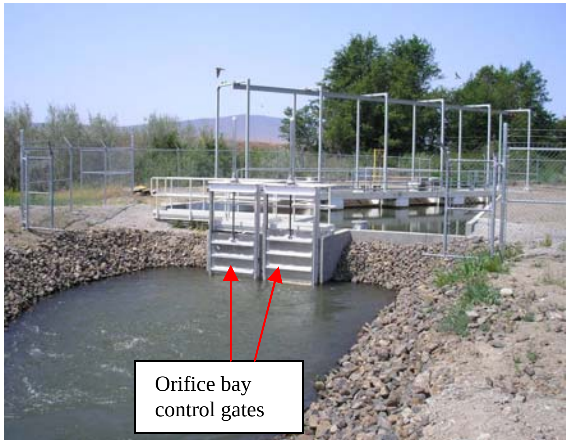


Figure 13. Submerged orifice weir showing the openings at the bottom of the structure and the forebay full of water. Water flows through the openings (orifice) at the bottom of the structure. Rate of diversion is controlled by a gate on the other side of the opening.

Ramp Flumes

Flumes are shaped, open-channel flow sections that force flow to accelerate and are generally used when head loss must be kept to a minimum, or if the water contains large amounts of suspended solids. Flumes are shaped, open-channel flow sections that force flow to accelerate. Acceleration is produced by converging the sidewalls, raising the bottom, or a combination of both. If only the bottom is raised, the flume is known as a long-throated ramp flume (also Replogle flume). Where the sides are converged and bottom raised, the flume is known as a Parshall flume. High velocities of flow help make flumes self-cleaning, and flow can be measured accurately under a wide range of conditions.

Long-throated Ramp Flumes (Figures 14 and 15) have only the bottom raised and have no side contractions. Upstream heads at one location relative to the control bottom elevation near the region of critical depth are used to determine the rate of diversion for measuring flow. On small diversions (0.45 to 6 cubic feet per second), flumes with adjustable ramps or fixed ramps (Figure 14) are available and can be installed using a shovel to dig in and place the flume, and a carpenters level to make sure the flume is level. Flumes with a fixed ramp are for flows from 3.5 to 180 cubic feet per second. Both types have staff gauges that read directly in cubic feet per second. Figure 17 shows how to read the staff gauge on portable flumes that have staff gauges that read directly in cubic feet per second. Ramp flumes in large channels (Figure 15) are designed and built in place and a separate rating curve developed for a specific flume. Ramp flumes can also be designed and used in small concrete ditches often found on farms and ranches (Figure 16) and inside culverts (Figure 17).

Figure 14. Long-throated ramp flume with direct read on staff gauge in cubic feet per second.

Figure 15. Long-throated ramp flume showing construction and operation in a large diversion canal

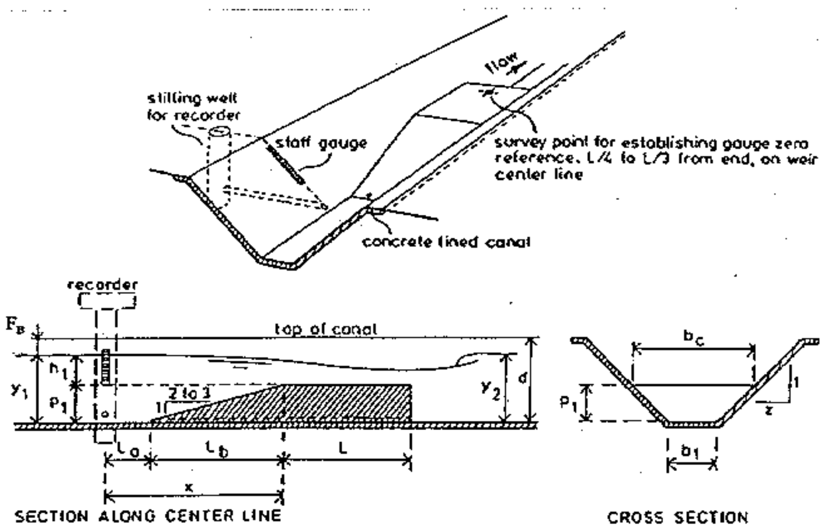


Figure 16. Specifications for long-throated ramp flume in concrete ditches

Figure 17. Long-throated ramp flume in culvert

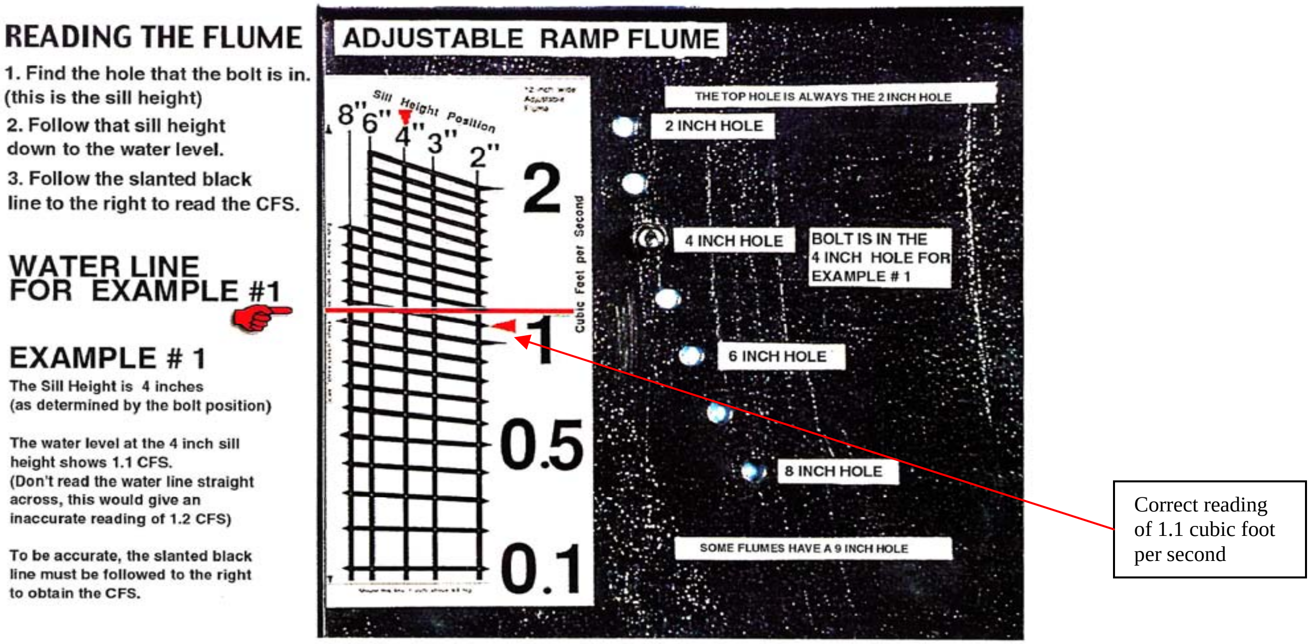


Figure 17. Reading the staff gauge in cubic feet per second on a small long-throated ramp flume

The Parshall flume (Figure 18) consists of a converging upstream section, a throat, and a diverging downstream section. Flume walls are vertical and the floor of the throat is inclined downward. Head loss through Parshall flumes is lower than sharp-crested weirs. Construction and placement must be precise because of the angles involved to form the proper shape of the flume to ensure measurements are accurate. A rating table is needed for each installation.

Figure 18. Parshall flume before installation and in-place and measuring water.

Electronic methods of measuring canal flow

In some situations, a user may want to measure water in open channels by using electronic methods and devices. The most common is a doppler meter attached to the bottom of a canal and wired to a data-logger (Figure 19). While not absolutely necessary, it is best to use a doppler meter in an engineered channel such as a short section of the canal lined with a concrete floor and two vertical sides of concrete. Using a doppler system in open channels does require a higher level of technical knowledge by the user for taking measurements needed to program the meter for this type of measuring system.

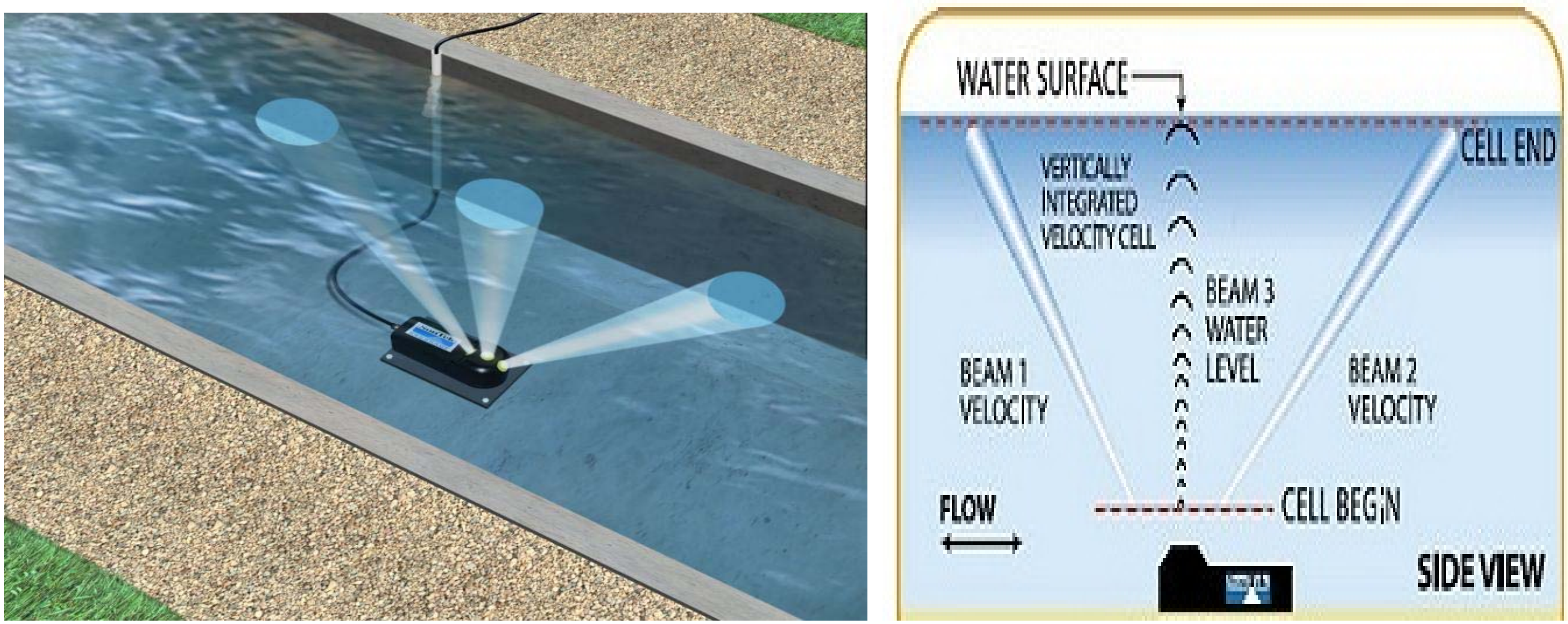


Figure 19. Doppler meter for use in open channel canals and ditches